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CARTESIAN-CELL BASED GRID GENERATION AND ADAPTIVE MESH REFINEMENT

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MOTIVATION

Wouldn't it be nice to just define the geometry and the free-stream conditions, and let the grid generation/adaptive refinement do the rest?

Objectives

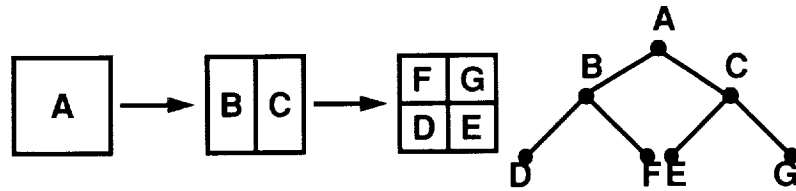
- Automated Grid Generation for Complex Bodies
- Automated Grid Refinement (Convergence?)
- Alternative to Triangular/Tetrahedral Meshes

A Cartesian-Mesh Approach

- Use Cartesian Cells of Unit Aspect Ratio to Create Background Mesh
- “Cut” Bodies Out of Background Mesh, Creating Irregularly Shaped Boundary Cells
- Arbitrary Numbers of Arbitrarily Shaped Bodies Are Allowed
- Geometry Defined With Sets of General Basis Functions Along Surfaces
- Background Mesh Created By Recursively Refining Cartesian Cell Into Four Cells

GRID GENERATION

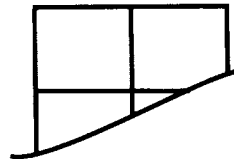
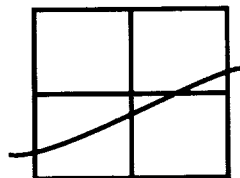
- Grid Generation Process Creates Binary Tree



- Binary Tree Allows Quad and Binary Refinement
- Connectivity/Tree Hierarchy Closely Related

GRID GENERATION

- Recur to Leaves of Tree and Determine Intersections (if any) with Bodies
- Use Simple Set of Rules to Determine If It is Legal to Cut Leaf into Cell: Recursively Refine if Illegal
- Vertex Locality Used to Determine Cut Cell Geometry



CELL CUTTING

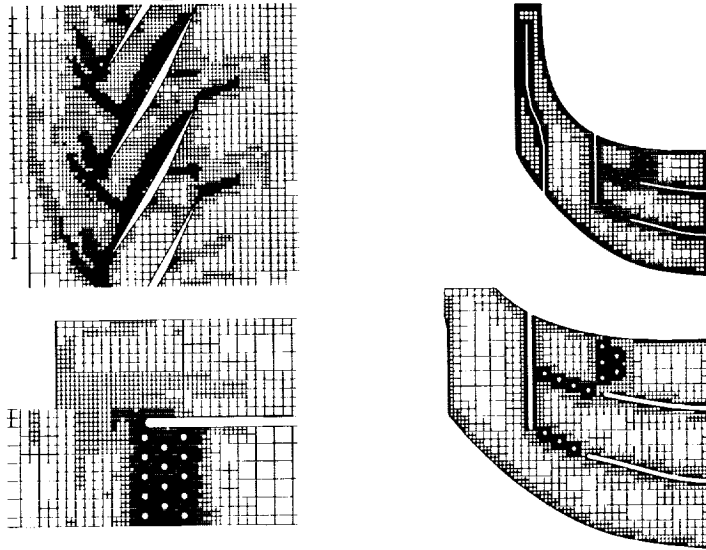
- **Example: Staggered Biplane Configuration of Clarke, Salas and Hassan (AIAA J. 1986)**



DATA STRUCTURE(S)

- **Cartesian Cell Geometric Data Inferred From Tree**
- **Cut Cell Geometric Data From (Local) Ordered List of Pointers to (Global) List of Vertices**
- **Connectivity Is Inferred Directly From Tree By Logical Tree Traversals (Centroid Compares, Face Matching)**
- **Code Written in ANSI C: Dynamic Memory Allocation/Deallocation, Self-Referential Data Structures**

SAMPLE GRIDS



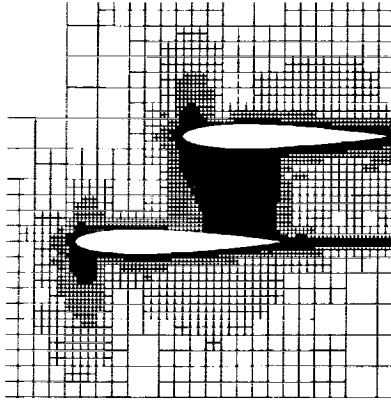
FLOW SOLVER FORMULATION

- Cell Centered, Finite Volume, Upwind Based Scheme
- Linear Reconstruction (Minimum-Energy) of Primitives Used to Compute Left/Right Interface States as Input to Approximate Riemann Solver
- Adaptive Mesh Refinement Using Cell Size Weighted Criterion Based on Velocity Divergence and Curl (Compressibility and Rotation)
- Perform Flow Solve/Adaptation Set Number of Times

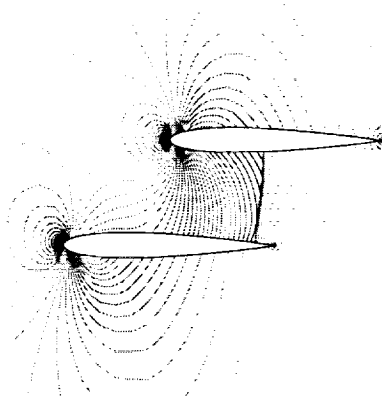
ADAPTIVE MESH REFINEMENT

- **Staggered Biplane Case**

Grid



Pressure Contours

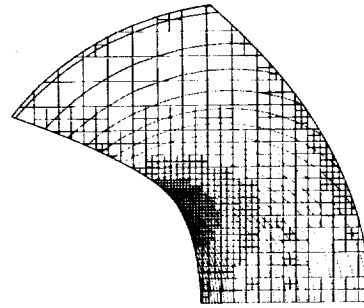
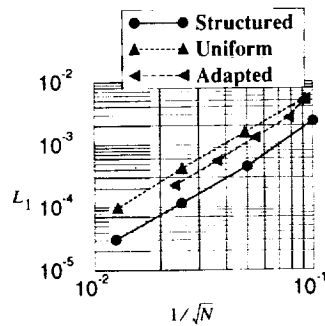


ACCURACY ASSESSMENT

- **Use Exact, Analytic Solution (Ringleb's Flow)**
- **Infer Order of Error From Uniform and Adaptive Refinement**
- **Infer Magnitude of Error by Comparing to Structured Solver**
- **Asks Question:**

Can Adaptive Mesh Refinement Beat Uniform Refinement and/or Structured Uniform Refinement?

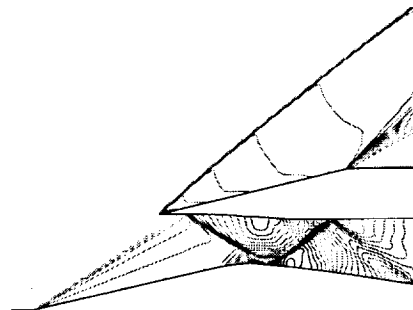
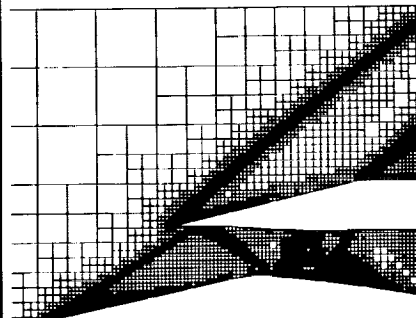
ACCURACY ASSESSMENT



- Approach is 2nd Order (Global), Better than 1st (Local)
- Smooth Flow: Can't Beat Uniform Refinement or Structured

ADAPTIVE MESH REFINEMENT

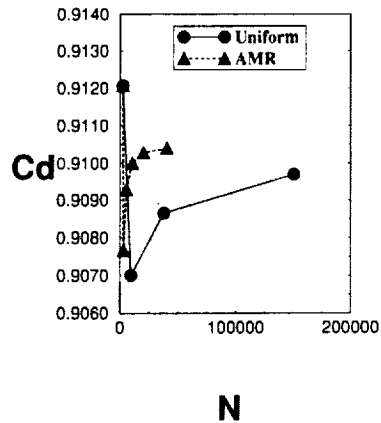
- What About Non-Smooth Flows?
- Grid Convergence Study on Supersonic, Axis-Symmetric, Mixed-Compression Inlet



ADAPTIVE MESH REFINEMENT

- Compare Uniform and Adapted Drag Coefficients

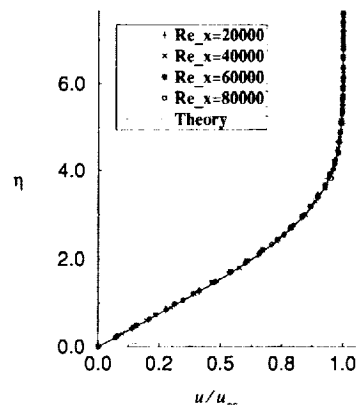
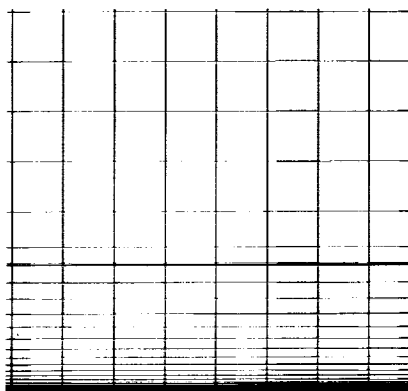
Conclusion



- AMR Grid Converged
- Uniform Not Converged (150,683 Cells!)
- Adaptive Mesh Refinement Best For Non-Smooth Flows With Multiple Length Scales

VISCOUS FLOWS

- Presently Extending to Viscous Flows
- “Cut” Level Distance Lines From Bodies



CONCLUDING REMARKS

- **Proven to be an Accurate Alternative to Triangular/Tetrahedral and Structured Grids**
- **Adaptive Refinement Best on Flows With Widely Varying Length Scales**

FUTURE DIRECTIONS

- **Can This Approach Work Well For Viscous Flows?
(Grid Smooth Enough With Distance Cutting?)**
- **What About 3D?**
- **WYSIWYG Front End?**

